

CALIFORNIA GEOLOGICAL SURVEY  
FAULT EVALUATION REPORT FER-247

**CHINO FAULT**

Riverside and San Bernardino Counties  
California

by  
Jerome A. Treiman

October 8, 2002

**INTRODUCTION**

The Chino fault, a northern splay of the Elsinore fault zone, bounds the eastern side of the Chino Hills (also called Puente Hills – see Figure 1). The fault extends southeasterly approximately 21 kilometers from the city of Chino Hills to the vicinity of Corona, where it merges into the Main Street fault of the Elsinore fault zone (Figure 2). The Chino fault was shown by Lawson and others (1908) and was named by English (1926). This fault is apparently a younger Neogene structure (McCulloh et al, 2000), whereas the Central Avenue fault, east of the Chino fault, is the present expression of an older tectonic boundary of the Puente block (Chino Hingeline fault of Wright, 1991). Although a reverse component of displacement on the Chino fault is discussed in several studies (e.g. Woodford et al, 1944; Gray, 1961; Olson, 1981), the current dominant sense of displacement appears to be right-lateral. Recent analyses of the Elsinore fault zone (Gath, 2000; Rockwell et al, 1992) suggest that the approximately 5-6 mm/yr of dextral slip along the Elsinore fault is shared by its two northern splays, the Whittier and Chino faults, with some slip also absorbed by folding.

The Chino fault has been previously evaluated in Fault Evaluation Reports 38 and 72. These previous evaluations did not find sufficient evidence for Holocene activity. The current re-evaluation is being made because new consulting studies have found evidence indicative of Holocene activity. This review also includes a more thorough review of aerial photographs to evaluate fault geomorphology.

**SUMMARY OF AVAILABLE DATA**

(faults from regional studies are shown on Figure 2; site-specific observations by Weber, 1977 are located on Plate I and summarized in Table 1; consultant studies are located on Plate I and summarized in Table 2)

**CENTRAL AVENUE FAULT**

According to McCulloh and others (2000) the Central Avenue fault marks the eastern margin of Paleogene strata in the Chino-Elsinore trough, with more than 1,000 m of post-Paleogene relief. They note that it is the “Chino Hingeline fault” of Wright (1991) and declare that it is an “old but fundamental break”. There is no evidence in the literature that it is currently an active fault, and no definition of its geometry beyond an inferred location based on groundwater data and its presumed role in uplifting granitic terrain to the east (Department of Water Resources, 1970; Fife and others, 1976; Gaede, 1969; Weber, 1977; and Wright, 1991).

## CHINO FAULT

Prior literature on the Chino fault was summarized by Smith (1977, 1978, 1979). The more useful early sources are Gray (1961), Durham and Yerkes (1964), Fife and others (1976) and Weber (1977). These are compiled on Figure 2. Subsequent studies (1:24,000 and larger) by Woodward-Clyde Consultants (1980) for Prado dam were summarized by Heath and others (1982), and these data are compiled on Plates Ia-c. Although data from Weber (1977) was published at 1:24,000, for the Chino fault it does not correlate with other data as well as that by Heath and others (1982), and hence is compiled here at the much smaller scale of Figure 2. A recently published map by Gray and others (2002) shows essentially the same mapping of the Chino fault as Gray (1961) and Weber (1977), but provides a little more detail of the adjacent Quaternary surficial units. The compiled sources show slightly varying fault trace locations. Numerous trenches from engineering geologic studies (Table 2) have corroborated some fault traces and indicated the absence of others. Trench locations are shown on Plates Ia-c with indication where faults were identified.

### *Geometry*

The Chino fault has a general strike of around N40°W. Petroleum industry data from the Mahalla oil field tells us that the Chino fault dips around 70° to the west at depths below 3000', shallowing to 50°W within the upper 1000' (Durham and Yerkes, 1964; Olson, 1977). Durham and Yerkes (1964) reported dips of dips 60-65°SW at Highway 71. Consulting studies (see Plate I) have shown variable dips in the near surface.

### *Sense of movement*

Gray (1961) said that the Chino fault was "apparently a reverse fault". Although he noted offset drainages and other features that suggested lateral displacement, he felt significant displacement was improbable based on other stratigraphic evidence. Trench exposures from numerous consulting studies, as well as oil field cross sections (Olson, 1977), commonly show a reverse sense of separation. Based on oil field data and interpretation, Olson (1977) describes 1000-2000 feet of vertical displacement [probably stratigraphic separation]. These data, along with geomorphic expression and some fault striae, indicate a compressional component of movement along this fault zone. A right-lateral strike-slip component is less well-documented, but is indicated by offset streams (Walls and Gath, 2001), mismatched stratigraphy in trenches (site 9, Plate Ib - Woodward-Clyde Consultants, 1980), and limited trench observations of striae in the fault plane (Weber, 1977; Heath et al, 1982; Walls and Gath, 2001). In spite of the "abrupt" thickness changes across the fault observed in trenches (often with little or no vertical separation) Woodward Clyde Consultants (1980) concluded that lateral offset was probably less than vertical, but provided no basis for this interpretation. Walls & Gath (2001) also summarized several lines of geomorphic evidence for right-lateral displacements (offset ridgelines, deflected drainages [75-300 m, possibly up to 550 m], scarps, beheaded drainages) and observed that right-steps accompany embayments in drainages (Appendix A). Mills and Collender (1995) reported grooves in some fault surfaces plunging 40° (it is not stated in which direction, but is described as "consistent with a right lateral component about equal to the vertical"). Ehlig (p.c., 1999) in reviews for the city of Chino Hills, proposed in 1996 that up to 3,000 feet (~1km) of right slip had occurred, based on his proposed original juxtaposition of drainages and ridges (Figure 3). Southern California Earthquake Center Group C (2001) pointed out a discrepancy between apparent transpression and the fault's orientation with respect to the Elsinore fault -- they noted that the fault should be transtensional based on its more northerly strike relative to the Elsinore fault.

### *Recency*

Older studies provided little evidence of Holocene activity on this fault, although there were abundant geomorphic indications of late Quaternary activity (Gray, 1961; Weber, 1977; Smith, 1977, 1978, 1979). Heath and others (1982; also Woodward-Clyde Consultants, 1980) also observed evidence of late Pleistocene activity, both from geomorphic evidence and from trench data at Prado Dam (site 9), but could not confirm Holocene activity. The studies by Woodward-Clyde Consultants (1980) found a ~125ka surface to be deformed across a faulted monocline with up to 25 feet of vertical displacement (folding and faulting) of the surface. Greater vertical separations (up to 60 feet) were observed for the base of the older alluvium underlying this surface.

Recent trenching for residential development at site 5 by Geolabs-Westlake Village (1999; also analyzed by Walls and Gath, 2001) has demonstrated that at least one portion of the Chino fault zone, in Chino Hills, has had Holocene displacement. At site 5a (see Table 2 and Plate Ia) the main strand of the fault extended into actively developing soil within 1 m of the ground surface; the base of this soil,  $^{14}\text{C}$  dated at  $10,925 \pm 275$  ybp, was faulted and warped 15-25 cm vertically (Walls and Gath, 2001 – see Appendix A).

Latest Pleistocene faulting is indicated in several other trenches where bedrock is displaced against older (undated) alluvium and some sites where slope wash deposits may be affected (e.g. site 7 - Plate Ia). At many of the sites where surficial deposits are not faulted these deposits are thin and probably too young to preclude Holocene activity. At site 14, shears were logged up to the modern surface of the soil (Medall & Assoc., 1978). Although this appears to be a well-developed late-Pleistocene soil (estimated from description of the Perkins gravelly-loam -- USDA-SCS, 1971), the preservation of the gouge zone and shears at the surface of this clayey soil suggests that the most recent shearing is much younger than the soil.

Trenches excavated by GeoSoils, Inc. (1995b) at site 21 (Plate Ic) exposed older fanglomerate underlying a remnant (knoll) of an uplifted surface estimated to be “at least about 100,000 years old”. Two trenches along the eastern margin of this knoll showed fracturing and easterly tilting of the older fanglomerate, although none of the fractures extended to depth in these exposures and no faults were observed. Younger colluvial wedges and other colluvial units, derived from the upper surface, were also observed in these trenches. They estimated that these younger deposits developed within the past 40 ka. Therefore, the only age control on the local deformation is that it is apparently younger than 40,000 years.

### *Slip rate*

Past estimates of slip rate have been rather poorly constrained and incomplete, based principally on vertical separations or offsets. For example, Heath and others (1982) estimated a vertical slip rate of 0.06 mm/yr based on a deformed paleosurface, and assumed that the lateral rate was less than this at Prado dam. Mills and Collender (1995) estimated a vertical slip rate of 0.14-0.25 mm/yr based on at least two events as indicated in their trenches. Coupled with their suggestion of roughly equal horizontal and vertical components, this would result in a total slip rate of ~0.2-0.35 mm/yr. Gath (2000) postulated that up to 2 mm/yr of dextral slip from the Elsinore fault zone is partitioned to the Chino fault, but some of this may be absorbed by folding. Walls and Gath (2001) revised this estimate, suggesting that 2.3-3.9 mm/yr NW strain is accommodated by faulting on the Chino fault and folding in adjacent terrain. Based on trench evidence for a most recent event and a penultimate event they estimated a minimum slip rate of 0.3-0.5 mm/yr (see Appendix A), a rate that is not too far off from the earlier estimate of Mills and Collender (1995).

## **SEISMICITY**

There have been two significant recent earthquakes in the vicinity of the Chino fault (Figure 2). On February 16, 1989 there was a M3.2 strike-slip earthquake at 4.3 km depth (strike 152°, dip 80° SW, rake 165°) on trend with the Chino fault. Hauksson and Jones (1991) inferred that this showed strike-slip motion on the Chino fault. A larger strike-slip earthquake (M3.9 at 13.8 km depth) occurred on December 14, 2001, and could be in the downdip vicinity of the Chino fault. Although the preferred focal mechanism strikes northwest, the conjugate solution aligns with the Chino fault. (Trinet web site <http://www.trinet.org/shake/9735129/zhu.html>)

## **AERIAL PHOTO AND MAP INTERPRETATION with DISCUSSION**

*Interpretation of aerial photographs from 1953 is shown on Plates IIa-d. Interpretation of more limited imagery from 1931 and 1938 is also included on Plates IIc&d. Locales A-M, discussed in this section, are also summarized in Table 3. Limited field reconnaissance was done over three days in July and August of 2001. Trenches at sites 6 and 5a were observed in 1994 and 1999, respectively.*

### **CENTRAL AVENUE FAULT**

The location of the **Central Avenue fault** is suggested by several linear tonal and vegetational features in the 1953 aerial photography (locales A-C, Table 3). These lineaments are within probably Holocene “recent alluvium” (Durham and Yerkes, 1964) overlain by very young soils (A/C profile – USDA-SCS, 1980). As indicated on Plates IIa and IIb, the lineations vary in length and straightness. Some of the shorter and straighter features may be agricultural or cultural. It is also uncertain if the features are strictly related to a fault or to older drainage patterns (which may or may not be fault controlled), although the straightness favors fault control. The tendency for the image tones northeast of the fault to be darker suggests the groundwater barrier on which the fault has been previously interpreted (Woodford et al, 1944; Department of Water Resources, 19970; Fife et al, 1976). There is also a suggestion in the photography, as well as the topographic map contours, that there may be a slight stream-incised scarp near the intersection of Ramona and Edison (locale B, Plate IIb), although this feature is no longer visible.

### **CHINO FAULT**

The Chino fault is expressed throughout its length as a late Quaternary fault, as indicated by beheaded, offset and incised drainages, linear drainages, shutter ridges, aligned saddles and scarps (Plates IIb, IIc & IId). Additional photo lineaments based on soil tones and vegetation indicate contrasting lithologies and soil moisture variations. Because of geologic differences that affect fault expression, it is useful to discuss the Chino fault in two sections: the *Chino Hills section* (north of the Prado Dam flood control basin) which is primarily within bedrock of the Miocene-age Puente Formation and the *Santa Ana Mountains section* (southward from Prado Dam) which is expressed almost entirely within Quaternary alluvial deposits.

#### *Chino Hills section*

The geomorphic and aerial photo evidence seem to indicate that this section of the fault is not as

continuous, in detail, as previous mapping might suggest. Its gross location is clearly indicated by several right-laterally offset or deflected drainages (Plates IIb-d, Figure 3 and p.A-5) -- features suggesting several hundred meters of late Quaternary offset, and perhaps as much as 1000 meters based on a postulated match of major drainages and ridgelines (P. Ehlig, pc., 1999). Mapping and photo interpretation for this project, as well as analysis by Walls and Gath (2001), suggests that at a finer scale the fault consists of a series of right-stepping segments. Small shutter ridges (near E and F, Plate IIb) appear to be bounded by these right-stepping faults. The interpreted pattern is locally confirmed by numerous trenches (e.g. site 7, Plate Ia) and exposures such as at site 4 (Plate Ia) where a tonal lineament in the aerial photos (Plate IIb) coincided with a shear zone exposed during tract grading (Pacific Soils Engineering, 1990). It may be that the *en echelon* pattern is a result of the fault rupturing through the steep bedding that strikes slightly more northwesterly than the trend of the fault. Bedrock, as mapped by Durham and Yerkes (1964) is Sycamore Canyon member (sandstone and conglomerate, with siltstone) of the Puente Formation.

The dominant sense of displacement appears to be strike-slip, as indicated by numerous deflected or offset drainages. Drainage analysis for this study corroborates the apparent offset identified previously by others (Figure 3 and Appendix). Actual present stream deflections vary from 25 m to several hundred meters. Interpreted greater offsets (obscured by stream capture) may be as much as 550 m (Walls and Gath, 2001) to 1000 m (P. Ehlig, p.c., 1999). Several windgaps along the fault zone (Plate IIc) indicate the larger offset drainages that have been pirated. An element of vertical separation is indicated at a broad scale by the uplift of the Chino Hills relative to the Chino basin to the east. Much of this uplift is likely related to folding, but some is probably also focused along the fault. At locale D (Plate IIb) the fault appears to vertically displace an older alluvial surface, as indicated by the break in slope and incised drainage. The soil survey for southwestern San Bernardino County (USDA-SCS, 1980) indicates the same well-developed soil (Chualar series) at locale D, at different elevations across the fault. Along the southern part of the Chino Hills section (Plate IIc) the fault marks a distinct change in topography, with generally steeper dissected terrain to the west. Several breaks-in-slope along the fault may be subdued fault scarps.

The interpreted fault pattern is a synthesis of geomorphic expression (Plates IIb and IIc), trench exposures (Ia and Ib) and older mapping. Holocene activity is judged based on trench exposures, geomorphic expression and the continuity of more subdued traces with better identified fault traces. The principal evidence of Holocene activity is from site 5a where the soil is clearly faulted; detrital charcoal from the base of this soil is ~11,000 years old and the fault extends upward into the lower calcic portion of the A horizon, judged to be late Holocene (Walls and Gath, 2001).

#### *Santa Ana Mountains section*

This section of the fault extends across older and younger alluvial fans derived from the Santa Ana Mountains and is generally not as strongly expressed as the Chino Hills section. However, where it is expressed there are unambiguous, albeit subdued, scarps across these alluvial surface remnants (Plates IIc, IId -- locales J, K, L & M). Geomorphic expression and previously mapped fault traces are corroborated locally by trenches (sites 9, 13, 14, 14a and 15, Plate Ic).

A right-lateral component of displacement is indicated by drainage offsets at locales K and L, as well as by inferred continuity with the Chino Hills section, and some element of compression or vertical motion is suggested by the generally east-facing scarps. Although faulted deposits have not been dated, Holocene displacement is possible above the scarp at site 14 (Medall and Assoc., 1978) where shears within a well-developed soil extend to the modern surface, and immediately west of locale M where a very late Pleistocene surface is faulted (see discussion below). Late Pleistocene

surfaces (>125 ka at locale J; >100-200 ka at locale M) are deformed and uplifted, and an undated but probably correlative surface is also faulted and folded at locale K. This correlation is based on soil survey data (USDA-SCS, 1971) which indicates that the deformed geomorphic surfaces at K and M have the same well developed soil (Perkins Series). The faulted surface at locale L may, similarly, be age-correlated with the lowest (and youngest) faulted surface west of locale M, based on the less-well developed soil (Arbuckle gravelly loam) mapped at these two locations. However, Gray and others (2002) map these latter two surfaces differently, as middle Pleistocene (Qof1) and late to middle Pleistocene (Qof), respectively. The lower surface at locale M is probably even younger as it is inset into the more broadly mapped Qof.

#### *Junction with the Elsinore fault (Local M)*

Locale M (Figure 4), where oblique compression at the junction of the Chino and Elsinore faults is evident, is particularly instructive. The terrain south of Chase Dr., between Hagador Canyon and Lincoln Ave, appears to be uplifted between the Elsinore fault on the southwest and an arcuate thrust fault to the north that is inferred to be related to the southern end of the Chino fault zone. Right-lateral motion on the Chino fault would be expected to result in oblique compression at this acute (15°) junction of the two faults. Primary evidence of tectonic uplift is geomorphic (e.g. the scarp-like slopes on the northern boundary of the elevated surface and on the northeast margin of a smaller remnant of this surface immediately east of Lincoln Ave). The main elevated surface, itself, includes an abnormal drainage pattern characterized by a now-breached closed basin behind its northern margin (interpreted to indicate upwarping of this inferred leading edge of the thrust). The antecedent drainage on the east side of the elevated surface, in maintaining its grade during uplift, has caused the gentle hill on the east (at site 21) to become isolated from the main surface. Further evidence that the two surfaces are related comes from soil survey data that shows the same soils (PgB/PgC - Perkins gravelly loam) on both features (USDA-SCS, 1971) and mapping of the same older fan deposit on both by Gray and others (2002). This strongly suggests a common age and origin for these two surface remnants. This same soil (PgB) is also mapped at a lower elevation to the north of Chase Drive and might be presumed to have once been part of the same surface. R. Shlemon is cited by GeoSoils (1995b, 2001) for the differentiation of two different age elevated surfaces, estimated (based on degree of soil development) to be at least 100,000 (PgB and PgC on the western and eastern parts of the uplifted terrain) to at least 200,000 years old (PgB in the central highest portion). These same deposits are identified as early Pleistocene by Gray and others (2002). The fault responsible for this uplift may continue southward, in the near subsurface, to the possibly fault controlled linear drainage at locale N. This projection is partially obscured by young Holocene fan deposits (Gray and others, 2002).

The younger inset fluvial surface (older Hagador Canyon floor) on the west flank of the uplift (AIC – Arbuckle gravelly loam) is offset vertically about 18 feet (~5.5 m), and may be right-laterally offset 50-100 feet (15-30 m) along a fault approximately along Chase Dr. The Arbuckle soil series has a B horizon with only weakly developed clay films and 10YR colors, as compared with the thick clay films and 2.5YR colors of the Perkins soils. Although Gray and others (2002) map this as a late to middle Pleistocene surface, they do not appear to have recognized, at the scale of their mapping, that this is a younger surface inset into the broader fan surface. The geomorphic position and lesser degree of soil development suggest that this abandoned and faulted Hagador Canyon floor is latest Pleistocene to perhaps Holocene. Even if slightly older, the considerable displacement probably represents more than one event, the latest of which are likely Holocene. The progressive vertical offset of these different age surfaces (AIC and PgB) indicate a history of repeated Quaternary displacements (Figure

5).

In summary, the northern margin of the uplift, along Chase Dr., is relatively abrupt and is probably accompanied by a fault, at or near the surface, that appears to have had multiple offsets in the latest Pleistocene to Holocene. To the southeast (site 21), the scarp appears more gentle and may be more of a fold-scarp with fault displacement occurring at an unknown but shallow depth. The previously interpreted lack of faulting at this site, in sediments presumed to be pre-Holocene, was the justification for judging (by the consultants) the northern portion of this site to be free of active faulting. Our current interpretation is that the ground surface on this portion of site 21, although not faulted, has been deformed as indicated by tilted fanglomerate (>100 ka) with tension fractures and younger colluvial wedges (<40 ka) recorded in the trench logs. If these colluvial deposits are related to a faulting/folding event this implies fault activity some time within the past 40 ka. There is no further age control on this deformation, but we presume it to be still active, based on the probable Holocene activity of the western portion of this uplift, the activity of other portions of the Chino fault, and the assumed interaction with the adjacent active Main Street strand of the Elsinore fault zone. Future fault rupture at site 21 could be expected to break to the surface or cause very localized deformation.

## **CONCLUSIONS**

### **CENTRAL AVENUE FAULT**

Although there are features visible in the aerial photographs that might corroborate a near-surface presence of the Central Avenue fault these features are not unambiguous enough to definitely attribute them to the fault. Furthermore, the fault effects that these features might reflect (groundwater barriers or older fault-controlled drainages) are not clearly indicative of Holocene activity.



## CHINO FAULT

The Chino fault shows clear evidence of dominant dextral displacement in the current tectonic regime, although the exact magnitude and timing of this displacement is uncertain. Continuity of individual traces of the Chino Hills section, as interpolated between trench exposures and geomorphic features, may be partially speculative, but the continuity and general trend of the zone of faulting is sufficiently well-defined that future fault investigations within the recommended zone will be able to identify the fault locations. The fault becomes less well-defined across the Prado Dam basin and through much of the Santa Ana Mountains section, only locally identified (sites 9, 13, 14 and 15 and locales J, K and L) until it joins the Elsinore fault at locale M. In this section of the fault Pleistocene deformation is apparent and Holocene activity is suggested by the evidence but has not yet been documented.

Primary surface expression of the fault is by deflected late-Pleistocene drainages in the Chino Hills section and subdued scarps and lesser stream deflections in the Santa Ana Mountains section. The lack of very fresh expression of the Chino fault is probably due to weak rocks and a low slip rate. However, continued activity of this fault zone is indicated by limited seismicity, Holocene faulting demonstrated at site 5a (Walls and Gath, 2001), possible Holocene activity at site 14, and the apparently continuing compressive deformation and faulting where the Chino fault joins the Elsinore fault (locale M). Localized deformation at site 21 and possible fault-related morphology at locale N suggest that an active or potentially active fault is present at an unknown, but probably shallow depth. It seems reasonable to conclude that active faulting and/or deformation is continuing at this junction with the Elsinore fault.

## **RECOMMENDATIONS**

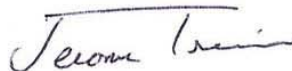
### **CENTRAL AVENUE FAULT**

Zoning is not presently justified for this fault.

### **CHINO FAULT**

The main trace of the Chino Hills section of the fault and certain secondary traces, including the junction with the Elsinore fault, as indicated on Plates IIIa and IIIb, should be included in new Alquist-Priolo Earthquake Fault Zones. The source for these fault locations is the interpretation of relatively continuous *en echelon* fault strands presented in this fault evaluation report, as corroborated by local trench exposures and geomorphic expression.

10/11/02  
Report reviewed  
& approved  
William A. Bryant  
EG 1554



Jerome A. Treiman  
Associate Geologist  
EG 1035



Table 1  
Features observed by Weber (1977) [with commentary for this FER]  
LQ= late Quaternary    VQ= very late Quaternary    H= Holocene

- LQ-1: vertically offset paleosol [*not verified*]
- LQ-2: displaced older alluvium [*not verified*] and deflected drainages [*not visible in aerial photos*]
- VQ-3: 1939 photo lineaments; age is queried [*not visible in 1931, 1938 or 1953 photos*]
- LQ-4: vague expression in older alluvium; age is queried [*coincides partly with short linear drainage in pre-dam photos, but may be mislocated from more obvious lineament to the west*]
- LQ-5: offset older alluvium in railroad cut [*not verified; another fault is visible in railroad cut in 1953 aerial photos*]
- LQ-6: displaced old alluvium [*not verified*]
- LQ-7: NE-facing scarp in older alluvium [*evident in 1931 and 1953 aerial photos*]
- LQ-8: subtle features in older alluvium exposed in temporary cut [*not verified; main zone corresponds to scarp*]
- LQ-9: orchard trees along fault show stunted growth [*not verified, but coincides with strong 1931 lineament*]
- H-10: vegetation lineament; age is queried [*not evident in 1931 or 1953 photos*]
- LQ-11: slight shear visible in cut [*not verified*]
- VQ-12: scarp; age is queried [*scarp is still evident, but appears to wrap westward around elevated area*]
- LQ-14: fan surface may be cut; age is queried [*faint tonal lineament in 1931 photography*]

Table 2  
Site Specific Studies

# on map summary (consultant)

Plate Ia

1. trenches found no faulting (RMA, 2000a & 2000b)
2. trenches reveal presence of SW-dipping fault placing bedrock over colluvium of uncertain but possibly Holocene age; soft to stiff clayey brown (10YR) colluvium rests on 25° slope (GeoSoils, 1994 & 1995a)
3. trenches encountered eastern portion of fault zone, with faulted alluvium; some areas of deep alluvium prevented complete exposure of the fault zone (Geolabs, 1998)
4. exposures during grading revealed a shear zone within Puente Formation in the canyon beneath the easternmost corner of the parcel (Pacific Soils, 1989 & 1990)
5. trenches encountered western portion of fault zone which displaces older alluvium; parts of the fault zone may be concealed beneath deep alluvium; numerous upper-plate faults appear west of the main trace, but activity was not demonstrated. (Geolabs, 1999); trench (site 5a) by Geolabs (1999), subsequently studied by Walls and Gath (2001), demonstrated Holocene activity of fault, based on faulting of “actively developing soil.”
6. trenches exposed significant displacement on main strand, although only vertical component was observed – Puente Formation was thrust over older alluvium (Pacific Soils Engineering, Inc., 1994); some slickensides observed during grading trend down dip (J.Franklin, pc, 2001)
7. trenches document two to three strands of the fault zone, but limited Holocene deposits do not provide sufficient age control (GeoSoils, 1990; J.Franklin, pc, 2001)

Plate Ib

8. two geotechnical studies noted offset drainages (including inset alluvium) and a fault zone that varied from 55' wide near Slaughterhouse Canyon to 130' wide near Abacherli Canyon. Faults were reported to extend into “B” soil horizon. [Maps showing location of trenches and geologic observations were missing from the reviewed reports (Lawmaster, 1983 & 1985)].
9. fault zone (up to 100 m wide) was clearly visible during dam spillway construction and in trenches; base of a paleosol (probably >125ka) had vertical separation of about 25 feet; bedrock/Qot contact may have up to 60 feet of vertical separation; mismatched stratigraphy across faults in trenches indicates strike-slip component; older alluvium (late Pleistocene) is displaced but soft silts (as young as Holocene) are not (Heath et al, 1982; Woodward-Clyde Consultants, 1980)

Plate Ic

10. no faults found in trenches (Scullin, 1977b)
11. additional trenches found no faulting on site (Highland Soils Engineering, 1987), thus constraining fault location (if active) to the west
12. no faults found in trenches, including several trenches excavated on trend with fault identified to the south (Scullin, 1977a)

13. southwest-dipping fault located in three trenches where reddish-brown fan deposits (probably Pleistocene) are displaced; surficial soil is not faulted (Pioneer Consultants, 1977)
14. fault exposed in trench displaces terrace deposits with shears extending through soil to the surface (Medall & Assoc., 1978); consultant also reports fault presence in trench offsite to the southeast (14a), but original log is unavailable.
15. a “subsidiary” fault was identified in trench, displacing presumed young gravel (RMA, 1986)
16. no faults found (Neblett, 1999a & b)
17. no faults found (ICG, 1990 & 1991; Neblett, 1999b); Neblett also include logs from prior study by Rasmussen
18. no faults found (Ranpac, 1990b; Hunt, 1994)
19. no faults found (Ranpac, 1990a)
20. no faults found in flat parcel immediately north of scarp (SID, 1997)
21. trenches did not find faulting but do document near-surface folding or tilting in Pleistocene fan deposits; report includes Soil Stratigraphic Age Assessment by Shlemon (GeoSoils, 1995b)
22. trenches focused primarily on locating the Elsinore fault zone, but also exposed soil profiles that indicate this elevated surface is from 100 to 200 thousand years old (GeoSoils, Inc, 2001)

Table 3  
Aerial Photo and Geomorphology Annotations (Locales A-M)

- A – Several NNW-trending vegetation and tonal contrasts indicate either changes in soil properties or soil moisture across each linear boundary. This is along the projection of the Central Avenue fault. See additional discussion under C.
- B – A minor tributary to Chino Creek has incised through what appears to be a localized escarpment that could be fault related. Barely discernible in the 1953 aerial photography, this feature is no longer present.
- C – This long, linear tonal contrast indicates a change in soil properties or soil moisture, or both. It could result from a fault (Central Avenue fault) in the upper stratigraphy, or could be controlled by a remarkably linear buried stream channel margin. In the latter case, the stream could have been fault controlled.
- D – An east flowing drainage is incised into the relatively uplifted terrain to the west of this eroded escarpment.
- E – Larger east-flowing drainages are markedly right-deflected 30-50 m. Several more deflected drainages are to the south. (see Plate IIa) Ridges also appear offset.
- F – A distinct shutter ridge is bounded by two fault strands. A right step in the fault is interpreted here from combination of aerial photo interpretation, trenching (Geolabs, 1999) and as-graded geologic map (Pacific Soils, 1990). Total right-lateral offset of the drainage may be as much as 200 m.
- G – Larger drainage (Slaughterhouse Canyon) is currently right-deflected more than 300 m, but another drainage to the northwest may be the original headwaters, now offset over 600 m. Note prominent windgap through which drainage may have flowed.
- H – Several small drainages are beheaded. at a prominent side-hill bench. Abacherli Canyon appears deflected at fault
- I – The axis of the alluvial fan associated with a small unnamed drainage appears to be dextrally offset as much as 50 m. A lineament in the alluvium reported here by Weber (1977 - from 1939 photos) was not verifiable in 1931 or 1938 imagery.
- J – Gentle scarp southeast of Prado dam is visible in 1931 and 1938 photos. The fault, itself, is visible in the spillway cut in the 1953 photography.
- K – Scarp and deflected channel margin within older alluvium is evident in aerial photography. Heath et al (1982) also noted vegetation lineaments and commented that a spring was shown here on an older map.
- L – West-facing scarp and right-laterally offset channel margin indicate location of fault.
- M – Area of uplift near the junction of the Chino and Elsinore faults is marked by offset, ponded and antecedent drainages and a scarp. (see Figure 4)
- N – A linear northwesterly-flowing drainage evident in aerial photography as well as an older topographic map may be fault controlled. (see Figure 4)

### AERIAL PHOTOGRAPHS USED

Fairchild      b/w 7x9      1"=1320'      flight C-1740      9/19/1931  
frames 4, 9-13, 33-37, 62-68, 96-103, 135-138, 171-174, 208-210, 244-247, 317-319, 346-348,  
372-373, & 392

USDA      b/w 9x9      1:20,000      1953  
AXL-40K      frames 39-46      2/11/53  
AXL-40K      58-65      2/11/53  
AXL-40K      77-83      2/11/53  
AXL-50K      66-72      3/03/53  
AXM-6K      104-109      9/23/53  
AXM-7K      2-4      9/23/53  
AXM-7K      26-31      9/23/53

## REFERENCES

(consultant reports are marked with an \*)

- Department of Water Resources, 1970, Meeting water demands in the Chino-Riverside area: California Department of Water Resources, Bulletin No. 104-3, Appendix A (Water Supply), 108 p., plates include Geologic Map (Plate 2) 1"=2 miles.
- Durham, D.L., and Yerkes, R.F., 1964, Geology and oil resources of the eastern Puente Hills area, southern California: U.S. Geological Survey Professional Paper 420-B, 62 p., 4 pl.
- English, W.A., 1926, Geology and oil resources of the Puente Hills region, southern California: U.S. Geological Survey Bulletin 768, 110 p.
- Fife, D.L., Rogers, D.A., Chase, G.W., Chapman, R.H., and Sprotte, E.C., 1976, Geologic hazards in southwestern San Bernardino County, California: California Division of Mines and Geology, Special Report 113, 40 p., plates 1:48,000.
- Gaede, V.F., 1969, Prado-Corona oil field: Summary of Operations, California Oil Fields, 55<sup>th</sup> Annual Report of the State Oil and Gas Supervisor, California Dept. Conservation, Division of Oil and Gas., p. 23-29.
- Gath, E., 2000, Tectonic geomorphic development of the southeastern Los Angeles and Orange County basins – a hypothesis (abst.): American Association of Petroleum Geologists, Program & Abstracts, p. A19.
- \*Geolabs-Westlake Village, 1998, Fault hazard investigation, tract 14285, easterly of Slate Drive and southerly of Soquel Canyon Parkway, City of Chino Hills, W.O.8533, September 28, 1998.
- \*Geolabs-Westlake Village, 1999, Preliminary fault location and activity assessment investigation, tentative tract 14551, easterly of Slate Drive, City of Chino Hills, California: unpublished consultants report, W.O.8533, June 30, 1999, 3 p., map 1"=200'.
- \*GeoSoils, Inc., 1990, Supplemental evaluation of faulting within previously mapped easterly zone and preliminary geotechnical design parameters, 350-acre parcel, Chino Hills, San Bernardino, California: unpublished consultants report, W.O.297-A-RC, February 20, 1990, 29 p., apps., map 1"=200'.
- \*GeoSoils, Inc., 1994, Geologic investigation, supplemental evaluation of faulting, Chino Fault, tentative tract 14652, City of Chino Hills, San Bernardino County, California: unpublished consultants report, W.O.717-A-RC, November 10, 1994, map 1"=100'.
- \*GeoSoils, Inc., 1995a, Response no. 2 to city review by Charles Abbott Associates, Inc. concerning GeoSoils, Inc.'s geologic investigation of the Chino fault, tentative tract 14652, City of Chino Hills, San Bernardino County, California, latest response dated December 22, 1994: unpublished consultants report, W.O.717-A-RC, January 20, 1995, map 1"=100'.
- \*GeoSoils, Inc., 1995b, Supplemental evaluation of faulting and geotechnical investigation, Chino fault, planning areas 21, 27, and 28, Mountain Gate, Corona, Riverside County, California: unpublished consultants report, W.O.1829-A-SC, May 30, 1995. [AP-3071]
- \*GeoSoils, Inc., 2001, Preliminary geotechnical investigation, tentative tract 29868, City of Corona, County of Riverside, California: unpublished consultants report, W.O.3641-A1-OC, March 23, 2001, 37p., apps., map 1"=100'

- Gray, C.H., Jr., 1961, Geology of the Corona South quadrangle and the Santa Ana Narrows area, Riverside, Orange and San Bernardino counties, California: California Division of Mines and Geology Bulletin 178, p. 1-58.
- Gray, C.H., Jr., Morton, D.M., and Weber, F.H., Jr., 2002, Geologic map of the Corona South 7.5' quadrangle, Riverside and Orange counties, California: U.S. Geological Survey Open-File Report 02-21 (version 1.0)
- Hart, E.W., and Bryant, W.A., 1997, Fault-rupture hazard zones in California: California Department of Conservation, Division of Mines and Geology Special Publication 42, Revised 1999, 38 p.
- Hauksson, E., and Jones, L.M., 1991, The 1988 and 1990 Upland earthquakes: left-lateral faulting adjacent to the central Transverse Ranges: Journal of Geophysical Research, v.96, B5, p. 8143-8165.
- Heath, E.G., Jensen, D.E., and Lukesh, D.W., 1982, Style and age of deformation on the Chino fault, *in* Cooper, J.D., comp., Neotectonics in southern California: Guidebook, 78<sup>th</sup> Annual Meeting, Geological Society of America, Cordilleran Section, Anaheim, California, p. 123-134.
- Hibner, T.H., 1999, Hydrogeologic evaluation of the Rialto-Colton basin and eastern Chino basin with emphasis on sub-flow across fault, San Bernardino County, California: unpublished MS thesis, California State University, Los Angeles, 246 p.
- \*Highland Soils Engineering, Inc., 1987, Geologic fault investigation, parcel 2, lot 46, Sierra del Oro, Corona, California: unpublished consultants report, Job No.07-3088-027-00-00, October 21, 1987. [C-727]
- \*Hunt, G.S., 1994, Geologic investigation for surface faulting, 23 acre parcel, tract 24077, west of Oak Ave., City of Corona, CA: unpublished consultants report, November 6, 1994. [Riv. Cnty GR-888]
- \*ICG, Inc., 1990, Fault hazard investigation, 10± acre residential development, tract 24118, Mangular Avenue, north of Chase Drive, Corona, California: unpublished consultants report, Job No.07-6739-007-00-00, October 24, 1990. [Riv. Cnty GR-799]
- \*ICG, Inc., 1991, Addendum to fault hazard investigation, response to county review, County geologic report No.799, tract 24118, City of Corona, California: unpublished consultants report, Job No.07-6739-007-02-00, October 18, 1991. [Riv. Cnty GR-799]
- \*Lawmaster, H.V., & Co., 1983, Engineering geologic investigation of the Chino fault line, Butterfield Site, Chino Hills, San Bernardino County, California: unpublished consultants report, File No.83-10098/751G-1, March 30, 1983 (maps missing from Chino Hills file copy).
- \*Lawmaster, H.V. & Co., 1985, Supplemental geotechnical investigation, Butterfield site, northeast of Chino fault zone, Chino Hills, San Bernardino County, California: unpublished consultants report, File No.85-10712, December 28, 1985 (maps missing from Chino Hills file copy).
- Lawson, A. C., and others, 1908, The California earthquake of April 18, 1906; Report of the State Earthquake Investigation Commission: Carnegie Institute of Washington Publication 87, 2 volumes, 452 p.
- McCulloh, T.H., Beyer, L.A., and Enrico, R.J., 2000, Paleogene strata of the eastern Los Angeles basin, California: paleogeography and constraints on Neogene structural evolution: Geol. Soc. Am. Bulletin, v.112, no.8, p. 1155-1178.



- \*Medall, S.E., & Assoc., 1978, Preliminary geologic and soil engineering investigation, tentative tract 9850, City of Corona, Riverside County, California: unpublished consultants report, W.O.994A, October 5, 1978. [C-336]
- Mills, M.F., and Collender, J.M., 1985, (abst.) Trench exposures of the Chino fault, Chino Hills, California – paleoseismic and engineering-geologic implications: AEG-GRA 1995 Annual Meeting, Diversity in Engineering Geology and Groundwater Resources, p. 72-73.
- \*Neblett & Assoc., Inc., 1999a, Fault investigation and preliminary grading plan review, tentative tract no.27285, City of Corona, County of Riverside, California: unpublished consultants report, Proj. No.212, May 5, 1999. [Riv. Cnty. GR-993]
- \*Neblett & Assoc., Inc., 1999b, Grading plan review, proposed residential development, tracts 24118, 27285 and 29385, east of Widgeon Drive and Mangalar Avenue, City of Corona, California: unpublished consultants report, Project No.188-F, November 5, 1999.
- Olson, L.J., 1977, Mahala oil field and vicinity: California Division of Oil and Gas, Report TR18, 21 p.
- \*Pacific Soils Engineering, Inc., 1989, Preliminary geologic/soil engineering study for offsite disposal fill area, tract 13507, 3-7, Chino Hills, San Bernardino County, California: unpublished consultants report, W.O. 101655, September 26, 1989.
- \*Pacific Soils Engineering, Inc., 1990, Addendum grading plan review, offsite fill area, tract 13507-3 through 13507-7, Chino Hills, County of San Bernardino, California: unpublished consultants report, W.O.101655, March 21, 1990.
- \*Pacific Soils Engineering, Inc., 1994, Chino fault study, revised tentative tracts 14425, 14426 and 14427, “Pinehurst” project, City of Chino Hills, California: unpublished consultants report, W.O.101720-RM, September 28, 1994, 16p, map 1”=100’
- \*Pioneer Consultants, 1977, Geologic evaluation of recent faulting, tract no.8090 – Corona area, Riverside County, California: unpublished consultants report, Job No.2466-001, March 22, 1977. [Riv. Cnty GR-69]
- \*Ranpac Soils, Inc., 1990a, Geologic fault evaluation, Chino fault splay, tentative tract 23434, City of Corona, California: unpublished consultants report, work order no.690-147, September 24, 1990. [C-762]
- \*Ranpac Soils, Inc., 1990b, Geologic fault evaluation, Chino fault splay, tentative tract 24077, City of Corona, California: unpublished consultants report, work order no.690-147, October 9, 1990. [Riv. Cnty GR-772]
- \*Richard Mills Associates, 1986, Concealed fault traces, tentative tract no.20966, Corona, California: unpublished consultants report, project no.85-295-01, February 25, 1986. [C-746]
- \*RMA Group, 2000a, Geologic fault investigation of proposed single family residential development, southwest corner of Bird Farm Road and Ramona Ave., Chino Hills, CA: unpublished consultants report, Job No.00-160-01, August 7, 2000, map 1”=30’.
- \*RMA Group, 2000b, Response to review of geologic fault investigation report, proposed single family residential development, southwest corner of Bird Farm Road and Ramona Ave., Chino Hills, CA: unpublished consultants report, Job No.00-160-01, October 19, 2000, map 1”=30’.
- Rockwell, T.K., Gath, E.M., and Gonzalez, T., 1992, Sense and rate of slip on the Whittier fault zone, eastern Los Angeles basin, California: Proceedings of the 35<sup>th</sup> Annual meeting, Association of Engineering Geologists, p. 679.

- \*Scullin, C.M., 1977a, Engineering geological-seismic evaluation and feasibility of development, lots 1-15, tract 7219, Rancho Corona Dr., Riverside County, California: unpublished consultants report, project #77129, March 15, 1977 [Riv. Cnty. GR-72; C-202].
- \*Scullin, C.M., 1977b, Engineering geological-seismic evaluation and feasibility of development, lots 1-20, tract 8830, Green River Road & Serfus Club Drive, Lorena area, Riverside County, California: unpublished consultants report, project #77217, December 17, 1977 [Riv. Cnty. GR-105; C-280].
- \*SID Geotechnical, Inc., 1997, Fault investigation, tentative tract no.27086, northwest corner of Lincoln Avenue and Foothill Parkway, City of Corona, California: unpublished consultants report, Project No.970005-02, November 11, 1997. [Riv. Cnty. GR-940]
- Smith, D.P., 1977, Chino fault: California Division of Mines and Geology Fault Evaluation Report FER-38, (unpublished), 11 p., 1:24,000.
- Smith, D.P., 1978, Elsinore fault zone, segment from Lake Elsinore to Prado Dam, Riverside County: California Division of Mines and Geology Fault Evaluation Report FER-72, (unpublished), 20 p., 1:24,000.
- Smith, D.P., 1979, Elsinore fault zone, segment from Lake Elsinore to Prado Dam, Riverside County: California Division of Mines and Geology Supplement to Fault Evaluation Report FER-72, (unpublished), 16 p., 1:24,000.
- Southern California Earthquake Center Group C\*, 2001, Active Faults in the Los Angeles Metropolitan Region: Southern California Earthquake Center, Special Pub. Series, No.001, September 2001, 47 p.
- USDA-SCS, 1971, Soil survey, western Riverside area, California: U.S. Department of Agriculture, Soil Conservation Service, 157 p., tables, maps (1:15,840).
- USDA-SCS, 1980, Soil Survey of San Bernardino County, southwestern part, California: U.S. Department of Agriculture, Soil Conservation Service, 64 p., tables, maps (1:24,000).
- Walls, C., and Gath, E., 2001 (abstract), Tectonic geomorphology and Holocene surface rupture on the Chino fault: 2001 SCEC Annual Meeting - Proceedings and Abstracts, Southern California Earthquake Center, p. 118. [<sup>14</sup>C dates and slip rate amended by personal communication, Walls, 2002]
- Weber, F.H., Jr., 1977, Seismic hazards related to geologic factors, Elsinore and Chino fault zones, northwestern Riverside County, California: California Division of Mines and Geology Open-File Report 77-4, 96 p, plates 1:24,000.
- Woodford, A.O., Shelton, J.S., and Moran, T.G., 1944, Stratigraphy and oil possibilities of Puente and San Jose hills, California: U.S. Geological Survey, Oil and Gas Investigations, Preliminary Map 23, 1:62,500
- \* Woodward-Clyde Consultants, 1980, Fault study report for Prado Dam, Riverside County, California: unpublished consultants report to the U.S. Army, Corps of Engineers.
- Wright, T.L., 1991, Structural geology and tectonic evolution of the Los Angeles basin, California *in* Biddle, K.T., ed, Active margin basins: Am. Assoc. Petrol. Geologists, Memoir 52, p. 35-134.

## Appendix A

Content of Poster Presentation of Walls and Gath (2001)

presented at the

2001 SCEC Annual Meeting  
September 23-26, 2001  
Oxnard, California

(<sup>14</sup>C data and slip rate amended per personal communication, Walls, 2002)

---

*published abstract (uncorrected dates)*

### **Tectonic Geomorphology and Holocene Surface Rupture on the Chino Fault**

Christian Walls and Eldon Gath  
Earth Consultants International

The Chino and Whittier faults serve as major sources of slip transfer from predominantly strike-slip rigid-block tectonics on the Elsinore fault in the south to folding and oblique-slip in the Los Angeles basin to the north. Paleoseismic studies on the Elsinore fault suggest a slip rate of 5.3-5.9 mm/yr and 2.5 +/-0.5 mm/yr on the Whittier fault. This suggests that 2.3-3.9 mm/yr of northwest directed strain is accommodated through faulting on the Chino fault and folding within the Puente Hills and Coyote Hills.

The tectonic geomorphology of the Chino fault indicates predominantly right-lateral strike-slip motion, based on northeast-facing fault scarps, saddles, offset ridgelines, deflected drainages, and beheaded drainages in the Chino Hills and northeast-facing fault scarps and vegetated lineaments in the alluvium near and southeast of Prado Dam. Clear deflections of the active drainages range from 25-100 meters whereas stream capture partially masks larger deflections of 400-500 meters. Right steps along the trace of the fault are coincident with embayments in drainage basins, suggesting local transtensional faulting.

A geotechnical trench placed across the principal surface trace of the fault exposed Puente Formation (Miocene) in fault contact with alluvium and buried soils. The vertical (N28W striking) main strand offsets the actively developing soil to within 1 meter of the surface. The base of the soil profile (BC1 horizon radiocarbon age 9,543 +/- 55 ybp) overlies but is not offset by a secondary fault, placing a maximum age of 9,598 ybp on the most recent surface rupture and a minimum age on the penultimate event. During the last event three soil boundaries were uniformly warped and vertically displaced (west side up) 15-25 cm. Underlying the active soil, a contact between an organic colluvial unit and a pebbly sandy clay loam (radiocarbon age 11,219 +/- 331 ybp) dips east and strikes orthogonal to the fault. Matching the apparent dips of this contact along the fault surface requires 4.2-5.6 meters of accrued right-lateral slip from two or more events in the last 11,550 years. Based on this data the average slip rate of 0.36-0.51 mm/yr on the Chino fault suggests that a significant portion of the slip budget must be accommodated on the Puente Hills and Coyote Hills structures.

## Tectonic Geomorphology and Holocene Surface Rupture on the Chino Fault (corrected dates)

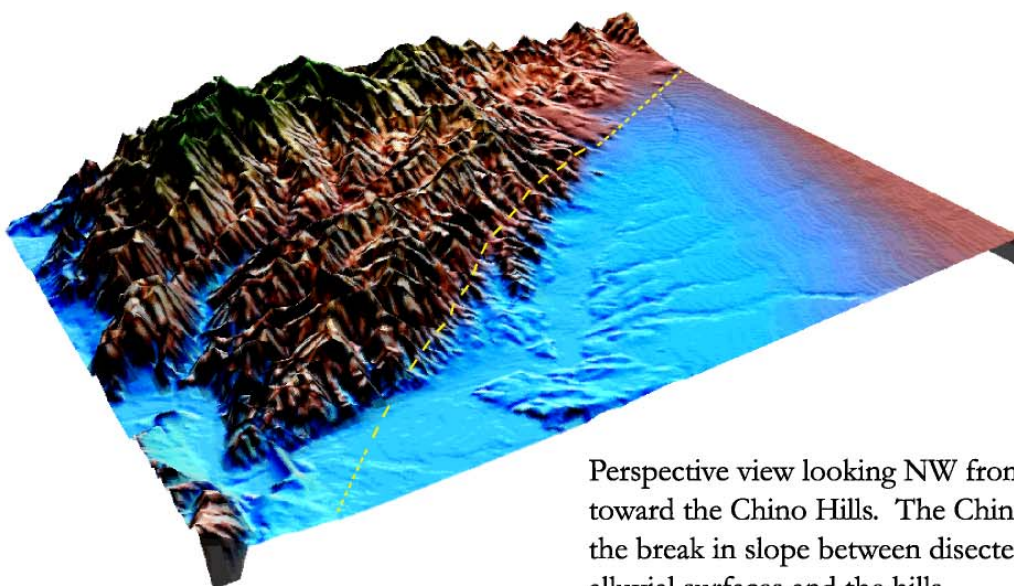
Christian Walls and Eldon Gath – Earth Consultants International

The Chino and Whittier faults serve as major sources of slip transfer from predominantly strike-slip rigid-block tectonics on the Elsinore fault in the south to folding and oblique-slip in the Los Angeles basin to the north. Paleoseismic studies on the Elsinore fault indicate a slip rate of 5.3-5.9 mm/yr and  $2.5 \pm 0.5$  mm/yr on the Whittier fault. This suggests that 2.3-3.9 mm/yr of northwest directed strain is accommodated through faulting on the Chino fault and folding within the Puente Hills and Coyote Hills.

The tectonic geomorphology of the Chino fault indicates predominantly right-lateral strike-slip motion, based on northeast-facing fault scarps, saddles, offset ridgelines, deflected drainages, and beheaded drainages in the Chino Hills and northeast-facing fault scarps and vegetated lineaments in the alluvium near and southeast of Prado Dam. Clear deflections of the active drainages range from 75-300 meters whereas stream capture partially masks larger deflections of 100-550 meters. Right steps along the trace of the fault are coincident with embayments in drainage basins, implying local transtensional faulting.

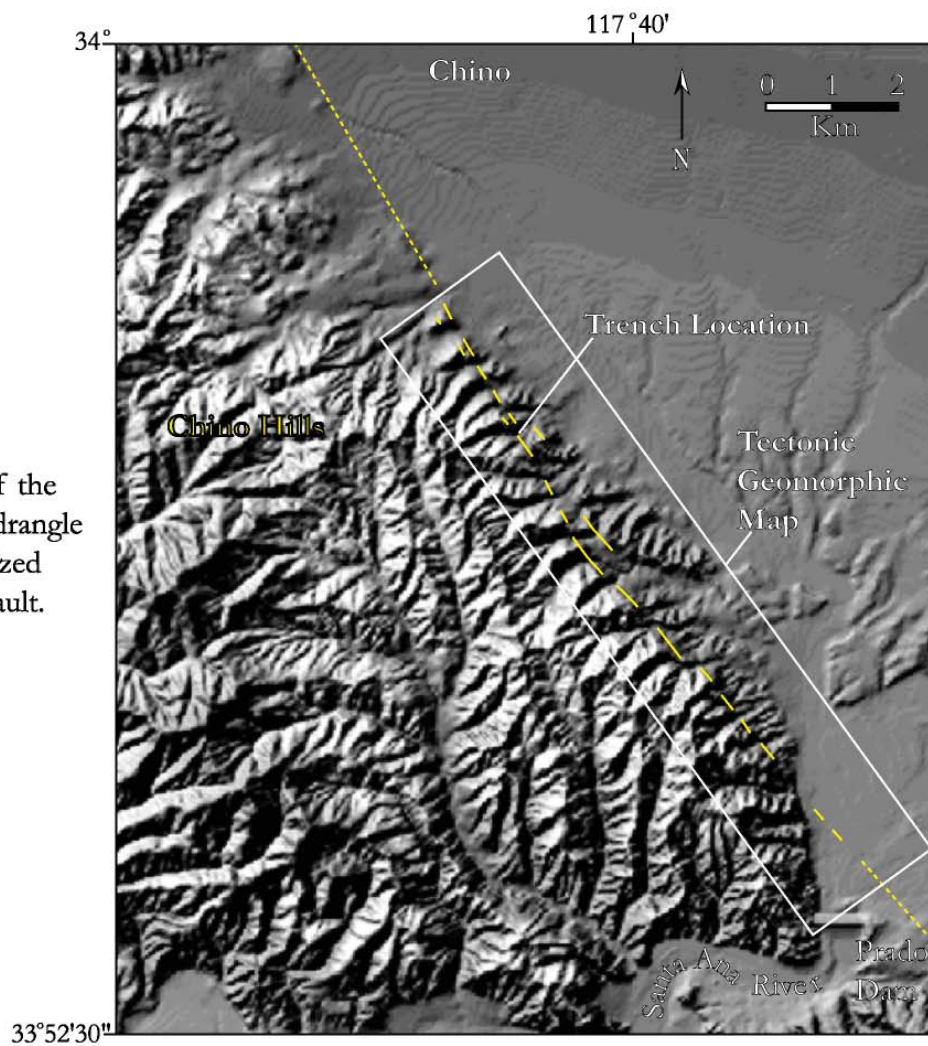
A geotechnical trench placed across the principal surface trace of the fault exposed Puente Formation (Miocene) in fault contact with alluvium and buried soils. The vertical (N28W striking) main strand offsets the actively developing soil to within 1 meter of the surface, implying a late Holocene surface rupture. The base of the soil profile (BC1 horizon radiocarbon age  $9,543 \pm 55$  ybp)  $10,925 \pm 275$  ybp overlies but is unfaulted by a secondary fault, placing a maximum age of  $9,598 \pm 11,200$  ybp on the most recent surface rupture and a minimum age on the penultimate event. The last event uniformly warped and vertically displaced three soil horizons (west side up) 15-25 cm. Underlying the active soil, a contact between an organic colluvial unit and a pebbly sandy clay loam (radiocarbon age  $11,219 \pm 13,250 \pm 950$   $\pm 331$  ybp) dips east and strikes orthogonal to the fault. Matching the apparent dips of this contact along the fault surface requires 4.7-6.1 meters of accrued right-lateral slip from two or more events in the last  $11,550$   $14,200$  years. Based on this data the minimum slip rate of  $0.41$   $0.56$  mm/yr is low relative to a 1-2 mm/yr rate derived from comparing deflections of similar stream orders on the Chino fault to the Whittier fault. A slip rate range of  $0.3$   $2.0$  mm/yr on the Chino fault equates to 0.3-3.6 mm/yr of northwest-directed slip that is accommodated on the Puente Hills and Coyote Hills structures.





Perspective view looking NW from the Perris block toward the Chino Hills. The Chino fault runs along the break in slope between dissected Quaternary alluvial surfaces and the hills.

Shaded relief map of the Prado Dam 7.5' quadrangle showing the generalized trace of the Chino fault.



*(this space blank)*

### **Tectonic Geomorphic Map**

Map shows trace of Chino fault and pervasive pattern of right-laterally deflected drainages. Many of the deflections went unrecognized due to the influence of stream capture on masking the deflections. Particularly persuasive is the consistent ~400 meter size of the offset, strongly indicating a tectonic rather than erosional cause. Note how the embayments of the drainages are located where traces of the fault make right steps. If these are indeed transtensional features then there is predominantly right-lateral motion on this fault.





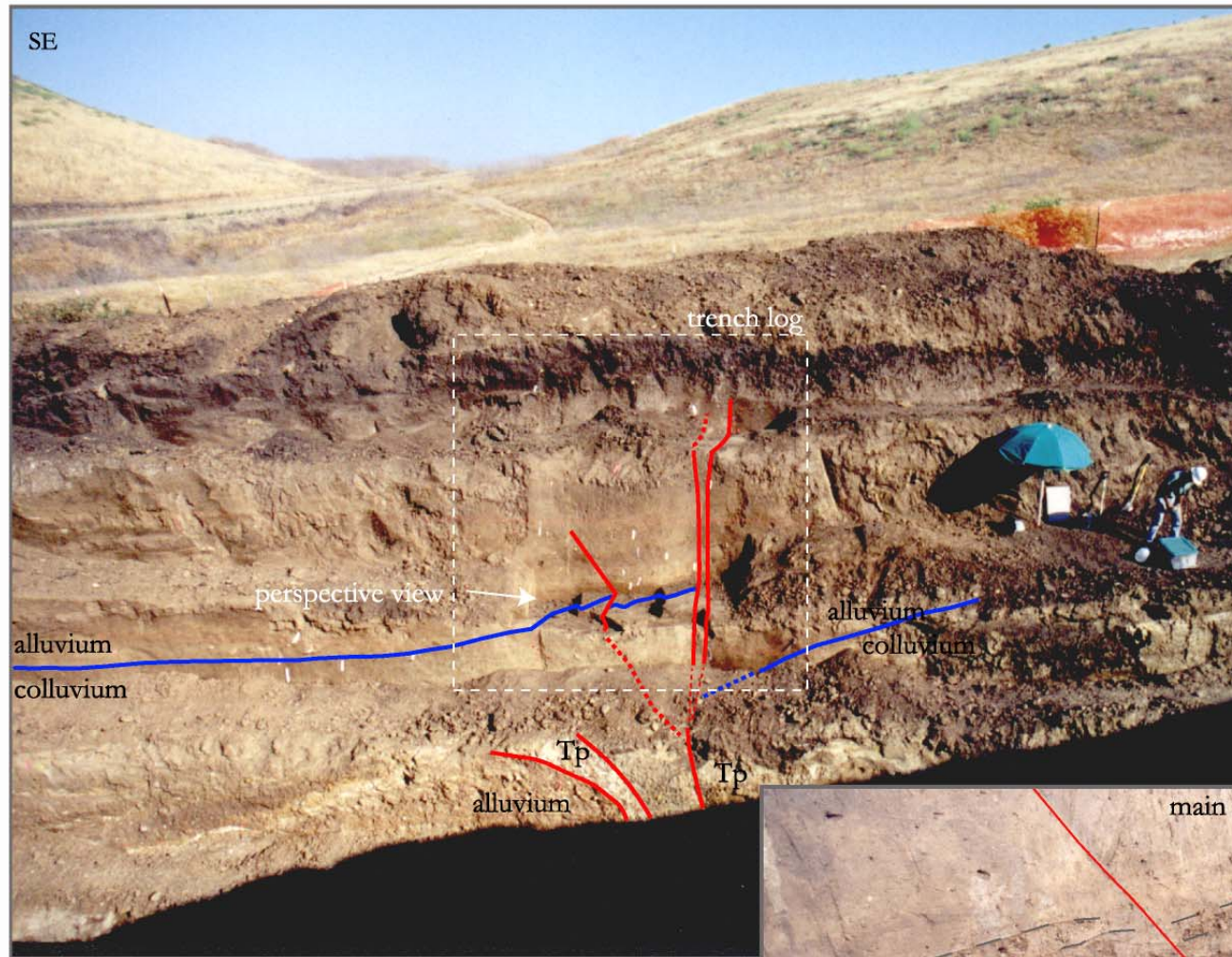


## Trench Log Observations

- 1) F1 faults the basal units up to the modern ABk horizon and possibly the base of the A2 horizon.
- 2) The Btk 1, Btk 2 and BC1 horizons are folded with 15-25 cm of west side up motion.
- 3) The contact between alluvium (Unit 1, 11,219+/-331 bp) and colluvium (Unit 2) is apparently offset vertically 1.3 m across F1. Given the observation that the overlying soil boundaries are up on the west side the contact is likely right laterally offset, with the dip of the contact giving the apparent vertical motion.
- 3) F2 faults the base of BC2 but does not offset the filled fracture or offset the overlying BC1 horizon (9,543+/-55bp).
- 4) The contact between alluvium and colluvium is apparently right-laterally offset 0.5 meters by F2 (see trench photo).
- 5) F3 offsets the filled fracture 10 cm.

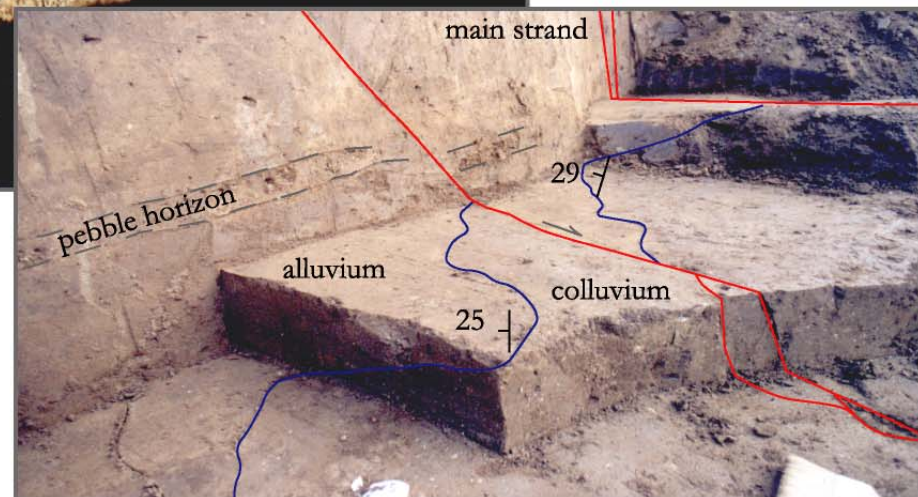
## Contact Reconstruction

An estimate of the total offset of the alluvium/colluvium contact is calculated by matching apparent dips across the fault surface. Using a 30 degree dip of the contact and a strike that is 40-50 degrees orthogonal to the fault produces an apparent dip of 20.5-24 degrees along the fault surface. Assuming no vertical motion 4.2-4.8 meters of right-lateral offset is required to match the apparent dips across the main fault. During the last event the soil boundaries were warped 15-25 cm. Using a minimum of 15 cm vertical motion per event and assuming there have been two events since deposition of unit 1, 4.9-5.6 meters of right-lateral offset is estimated. Adding the 0.5 m offset on F2 places the total estimate of right-lateral offset at 4.7-6.1 m.

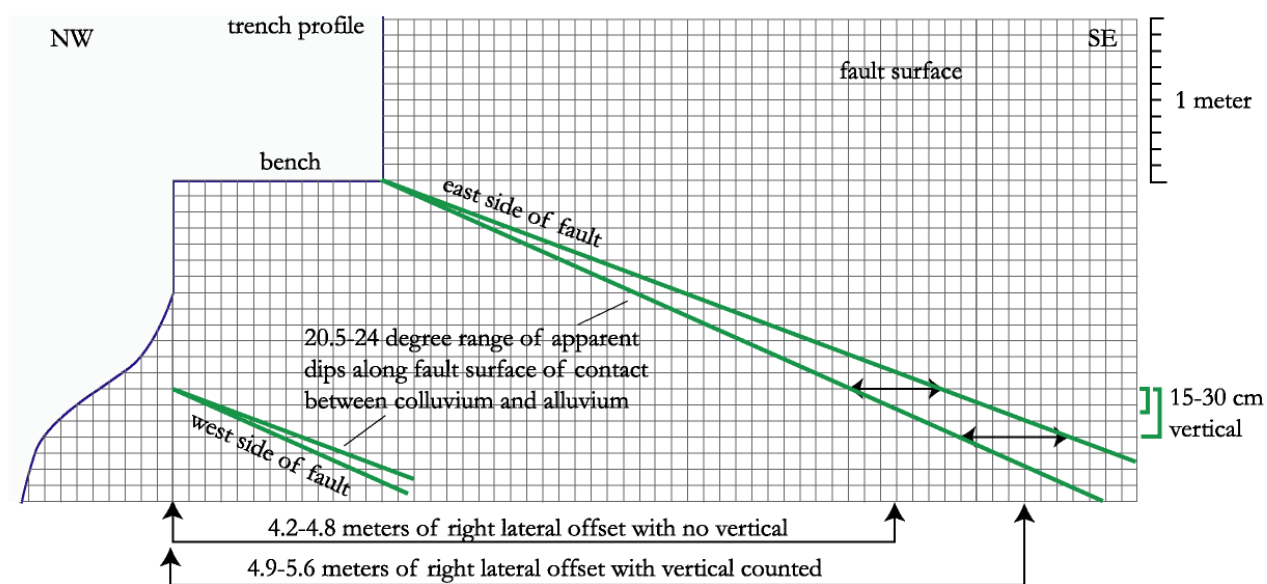
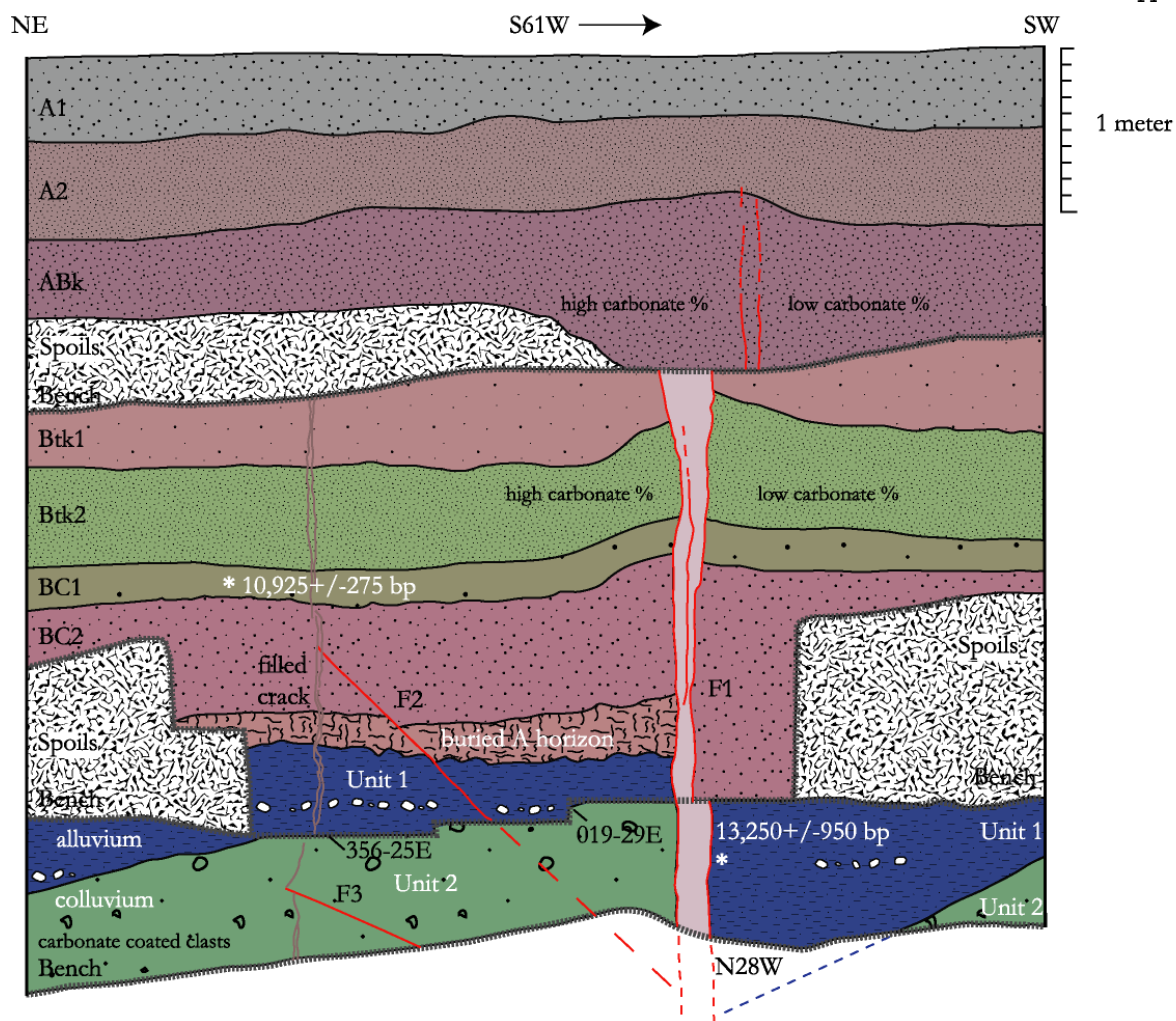


View of trench exposure looking SE. The main fault offsets the modern soil up to the ABk horizon (below the dark A1 and A2 horizons), indicating a late Holocene surface rupture. On the lower bench Puente FM is faulted over mainstream alluvium. A secondary strand offsets the contact between colluvium and alluvium but does not fault the upper horizons of the modern soil. Another geotechnical trench placed across the saddle in the distance exposed the fault.

Perspective view of secondary fault where it offsets the contact between colluvium and alluvium. Apparent right-lateral offset is 0.5 m. Strike and dip of the contact was measured and used in estimating the total slip across the main fault (see trench log).







## Conclusions of Walls & Gath (2001)

At least one surface rupture event has occurred on the Chino fault in the last ~~9,598~~ <sup>11,200</sup> years. Based on the faulted ABk horizon, within 1 meter of the surface, this event was late Holocene.

The penultimate event occurred between ~~9,488~~ <sup>10,650</sup> and ~~11,550~~ <sup>14,200</sup> years ago.

The minimum slip rate is ~~0.41-0.56~~ <sup>0.3-0.5</sup> mm/yr.

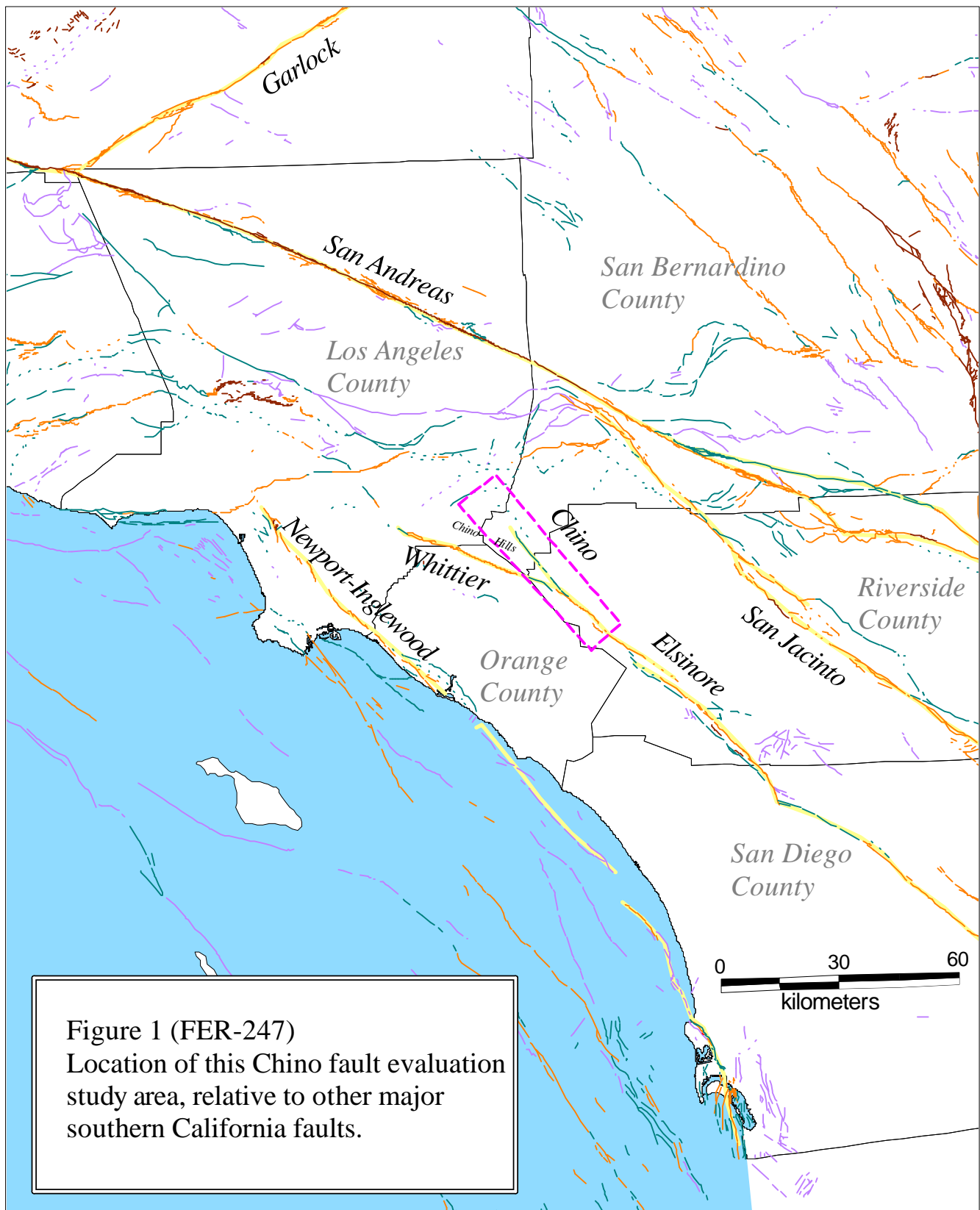
Active drainages are right-laterally deflected 75-300 meters.

Captured and beheaded drainages have been deflected 100-550 meters. Five are deflected ~400 meters.

Right steps in the fault are coincident with embayments in the drainages, suggesting local transtensional faulting occurs on a predominantly right-lateral strike-slip fault.

## Comments

The slip rate calculated in this exercise is low compared to an estimate inferred from the deflected drainages. Drainages of the same stream order are offset about 30-50% more across the Whittier fault, which has a slip rate of  $2.5 \pm 0.5$  mm/yr, suggesting that the Chino fault slip rate should be 1.0-2.1 mm/yr. A couple explanations for the lower than expected slip rate are as follows: 1) At this trench site there may be more than two events resulting in a greater amount of accrued vertical offset not accounted for. 2) We assumed that the alluvium/colluvium contact has a uniform strike and dip. Three-dimensional changes in the attitude of the contact would likely require a larger amount of accrued slip to produce the exposed stratigraphic relationships.



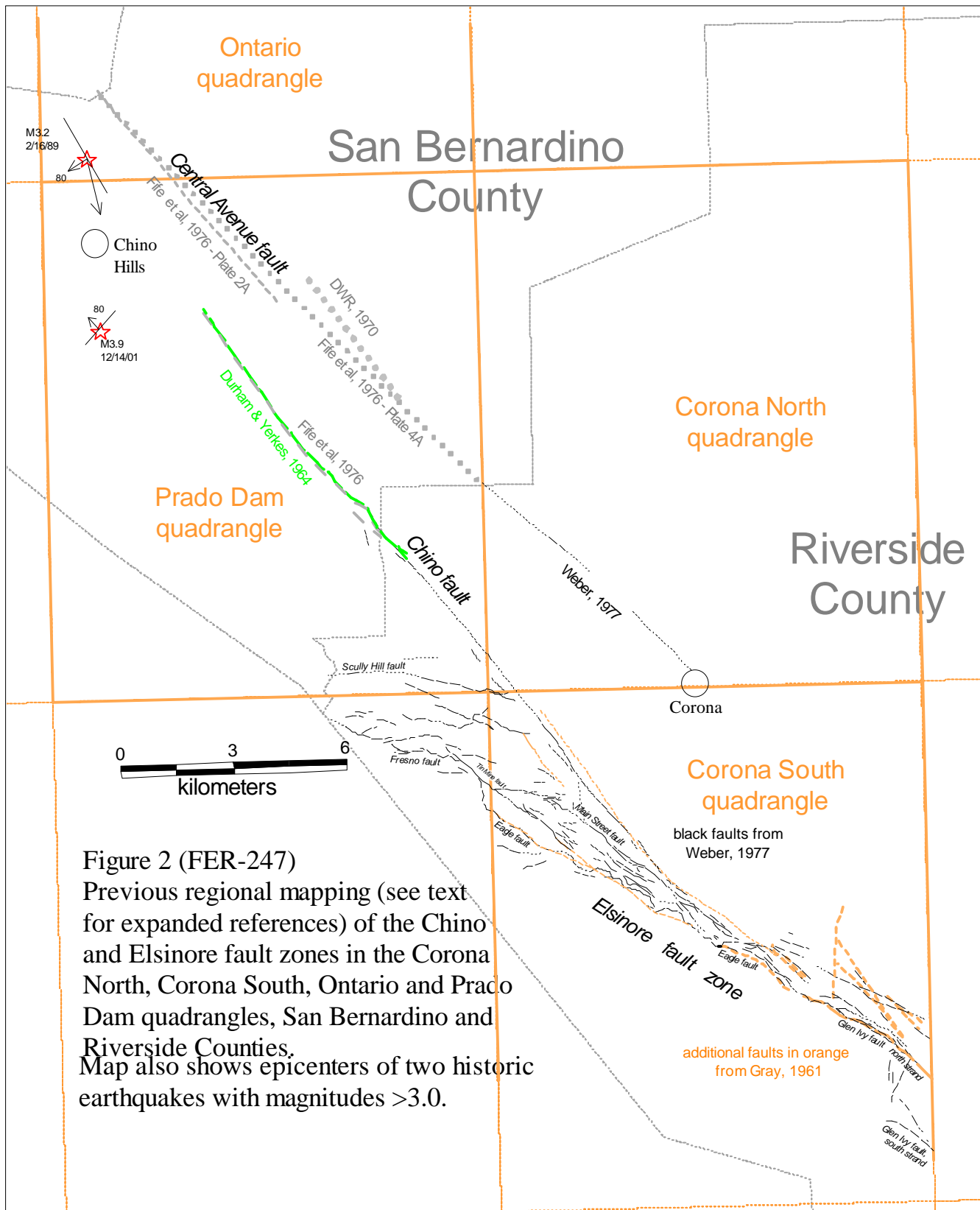
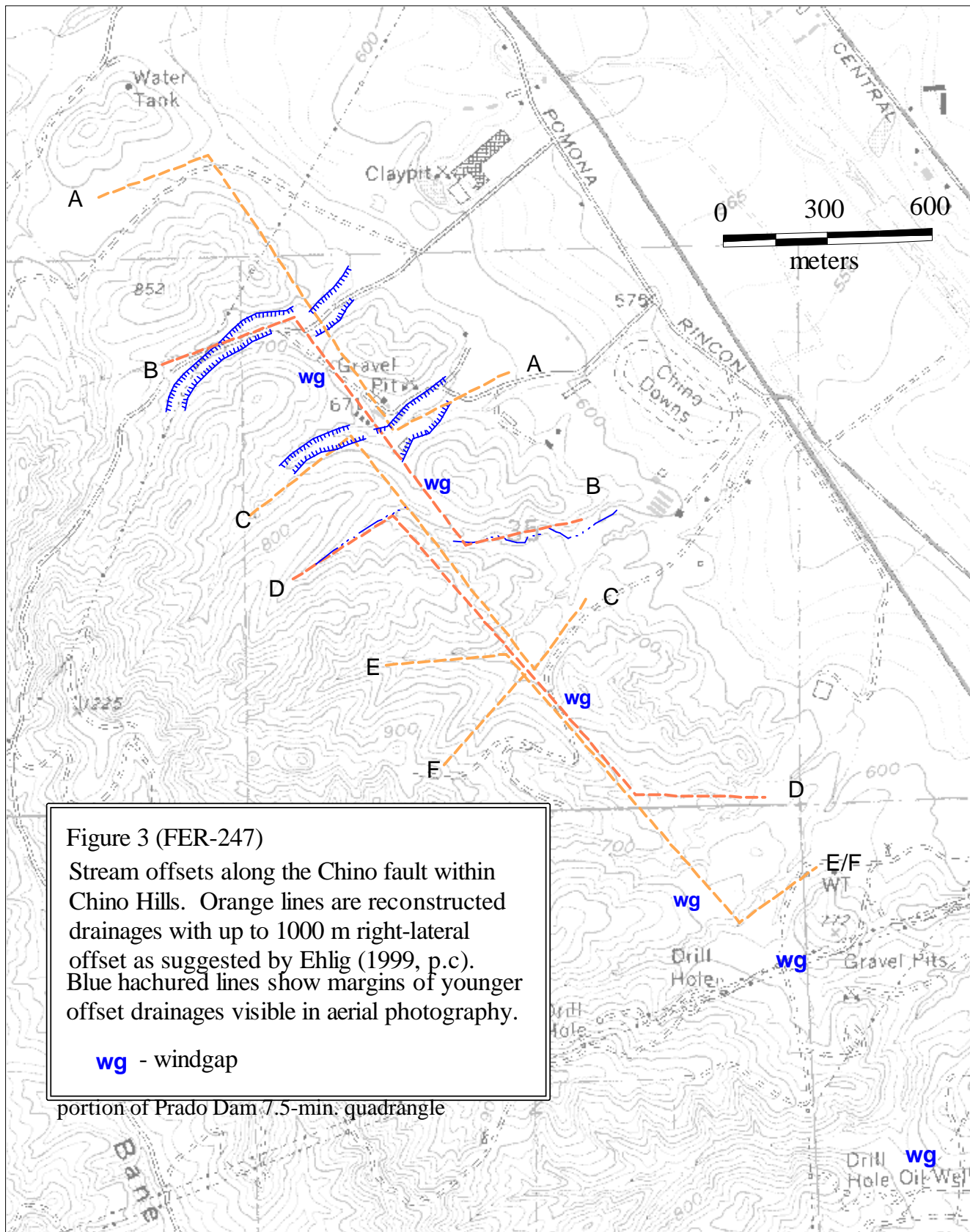
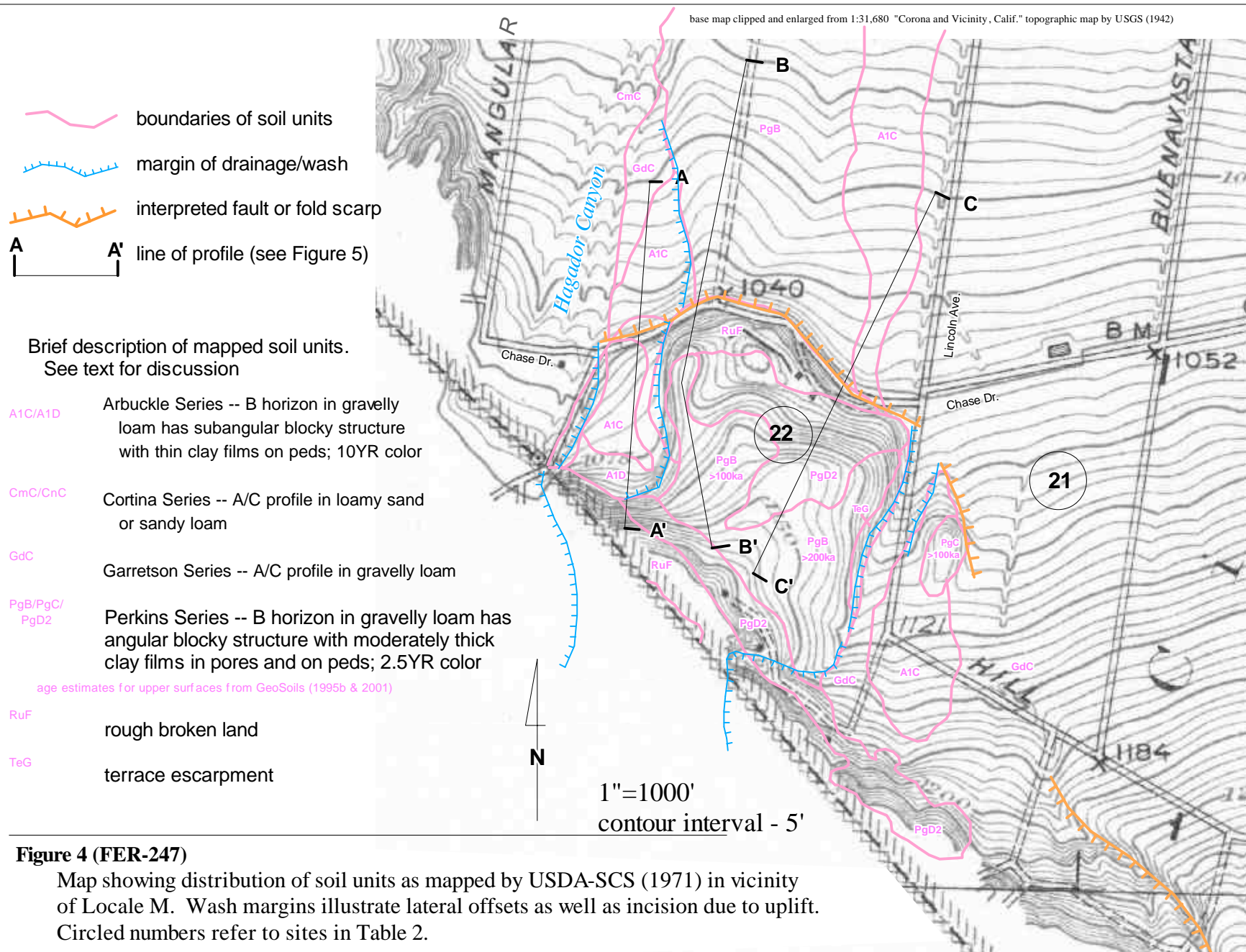


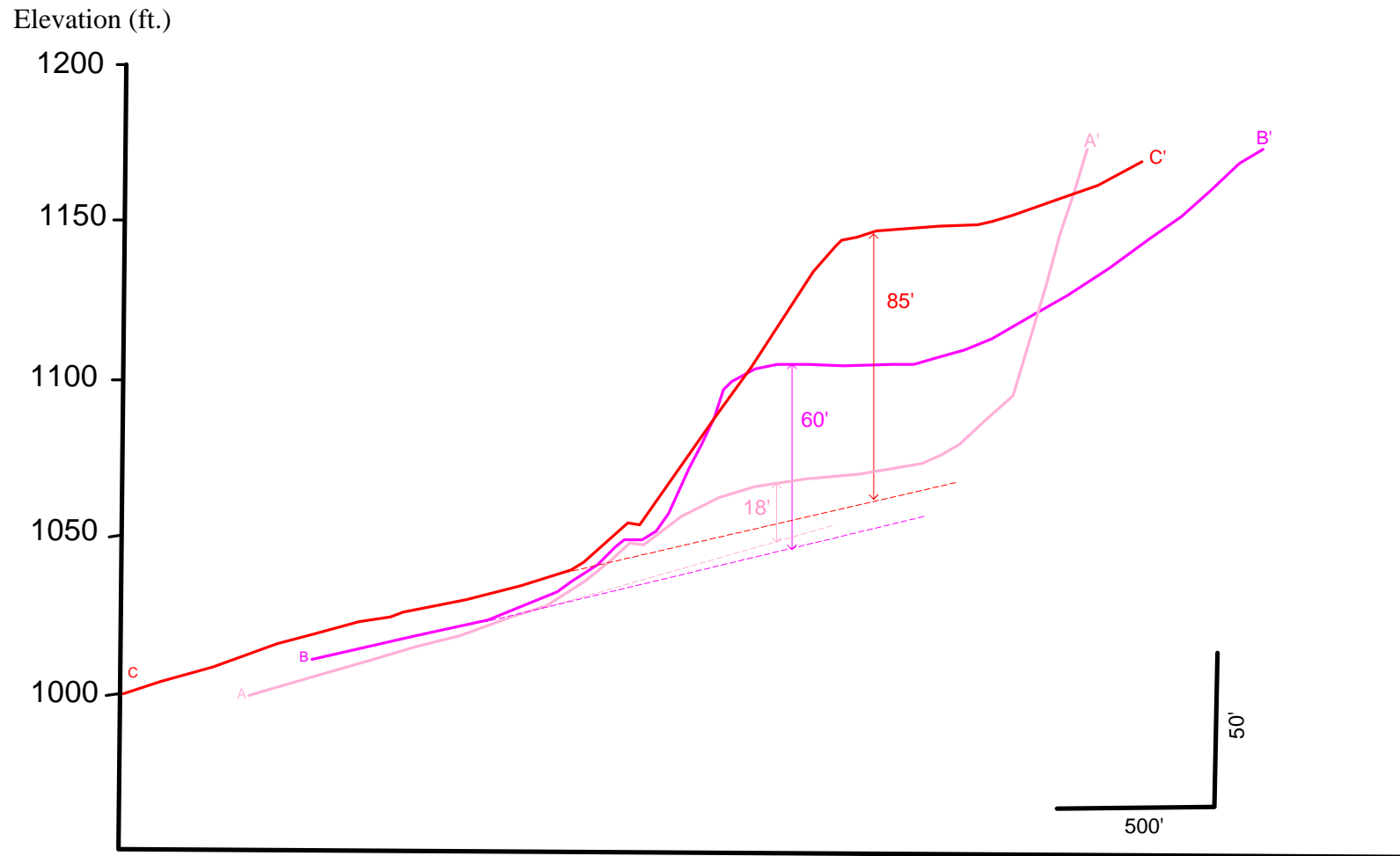
Figure 2 (FER-247)  
 Previous regional mapping (see text for expanded references) of the Chino and Elsinore fault zones in the Corona North, Corona South, Ontario and Prado Dam quadrangles, San Bernardino and Riverside Counties. Map also shows epicenters of two historic earthquakes with magnitudes >3.0.











**Figure 5 (FER-247)**

Profiles across scarp demonstrate increasing uplift with age of the surface. Profile A-A' is across latest Pleistocene surface (Arbuckle soil). Profile B-B' and C-C' are across surfaces estimated to be greater than 100,000 and greater than 200,000 years old, respectively (GeoSoils, Inc., 2001). Vertical exaggeration is 10:1. See Figure 4 for profile locations.